Low Energy RHIC electron Cooling

Beam Dynamics Simulations

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LEReC Review
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BROOKHAVEN NATIONAL LABORATORY
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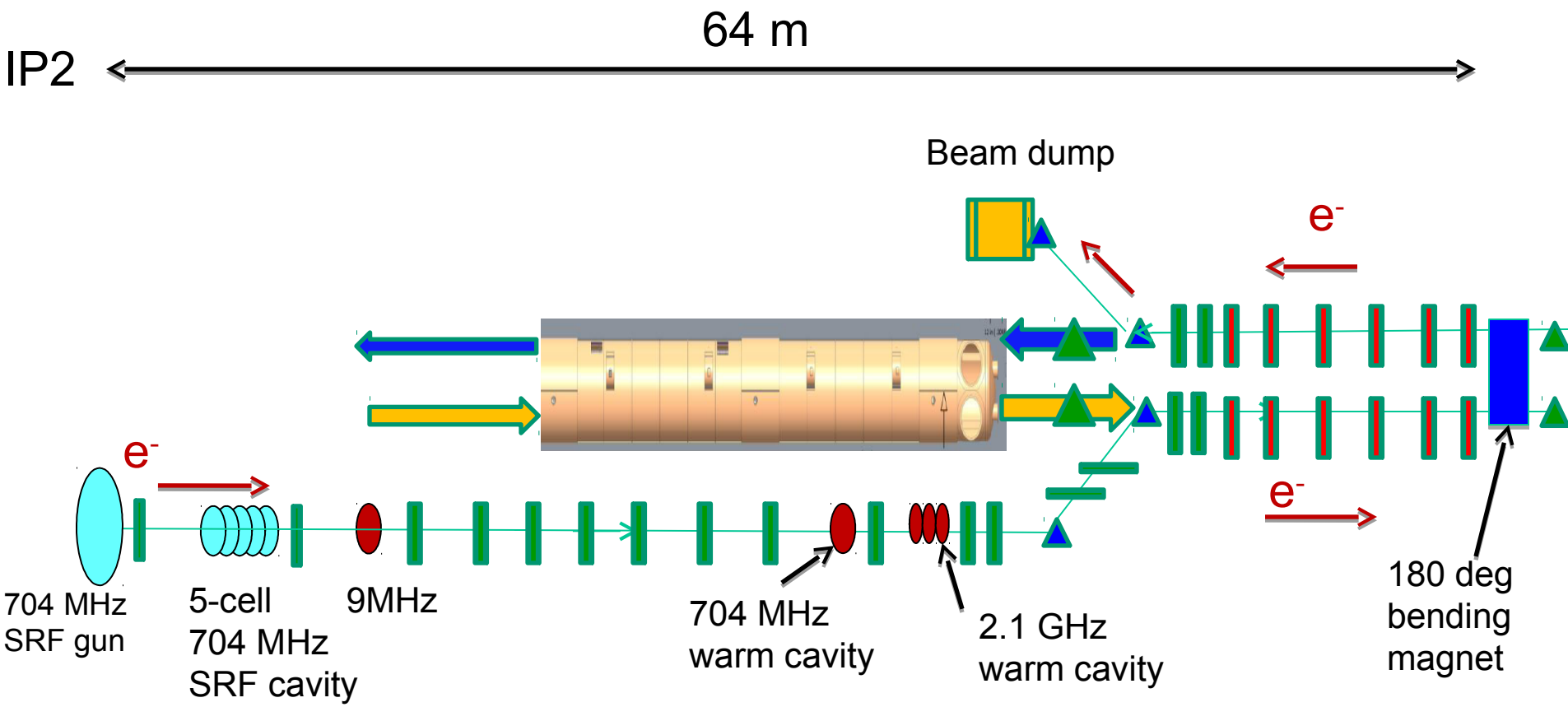
Requirements

Gun Energy [MeV]	Gamma	Charge per bunch [pC]	Beam Power [kW]
1.6	4.13	100	45
1.8	4.52	100	51
2.0	4.91	100	56

	Parameters need for ultimate cooling performance
Normalized Emittance	< 2.5e-6 m
Energy Spread	5e-4

LEReC-I (1.6-2MeV): Gun to dump
SRF gun used as a gun

12/02/14



Layout

- SRF gun provides beams up to 2 MeV
- 5 Cell SRF cavity is used to create energy chirp for stretching of the bunches
- SRF gun and 5 cell cavity are too high to be located in the tunnel. The long transport line
  - allows ballistic stretching of the bunch
  - increases energy spread through space charge
- Warm 700 MHz cavity removes linear energy chirp
- Warm 2100 MHz cavity removes 2nd order energy chirp. The cavity is placed where the bunch is long, so that less RF power is needed.

Layout

- Dog leg section for merging with the ion beam
  - uses chevron magnets to keep the beam round
  - 2 solenoids to make the dog leg achromatic
- Strong solenoids before and after dog leg adjust beam size in the cooling section
- Weak solenoids in the cooling sections minimize the beam divergence
- A single 180 degree (non achromatic) turn-around dipole degrades the emittance less than an achromatic beam line.

Simulations

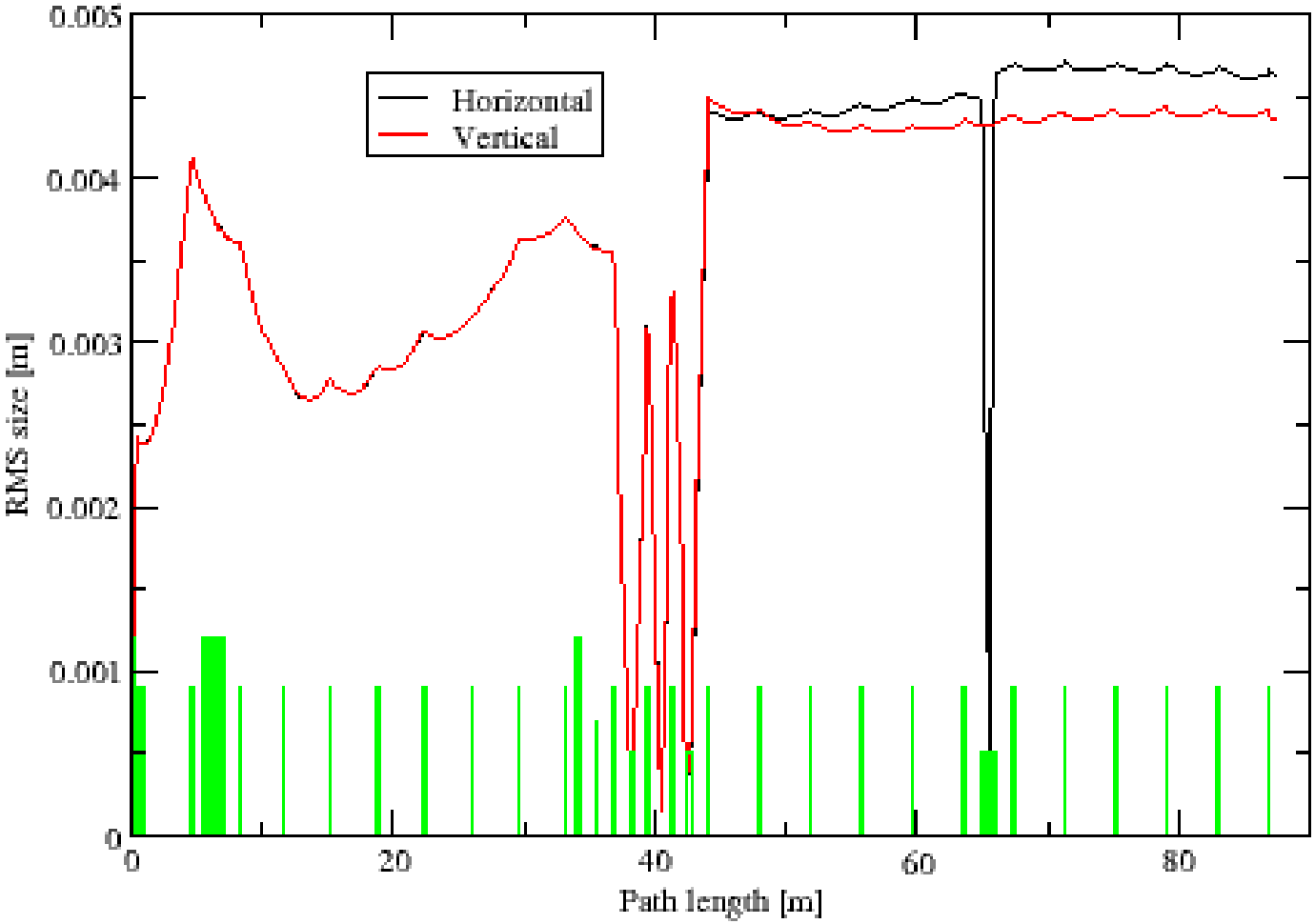
- All simulations were made using the code PARMELA
- PARMELA is a 2-D program that assumes for the space charge calculations that the beam is round. Since we keep our beams round PARMELA is an appropriate tool
- A multi-threaded optimizing program (written at BNL) was used which launches PARMELA for the function evaluation

Beam optics with SRF gun at 1.6MeV

- We have a solution that fulfills the requirements
- We use a 10% higher bunch charge and ignore 10% of the particles with the worst energy deviation. These particles do not cool the ion beam, but they do not hurt.
- There is no “emittance compensation” since we do not accelerate to high energies to “freeze” the emittance.
- The longitudinal space charge forces are a bigger problem than the transverse forces
- We use longitudinal bunch shaping to minimize the energy spread

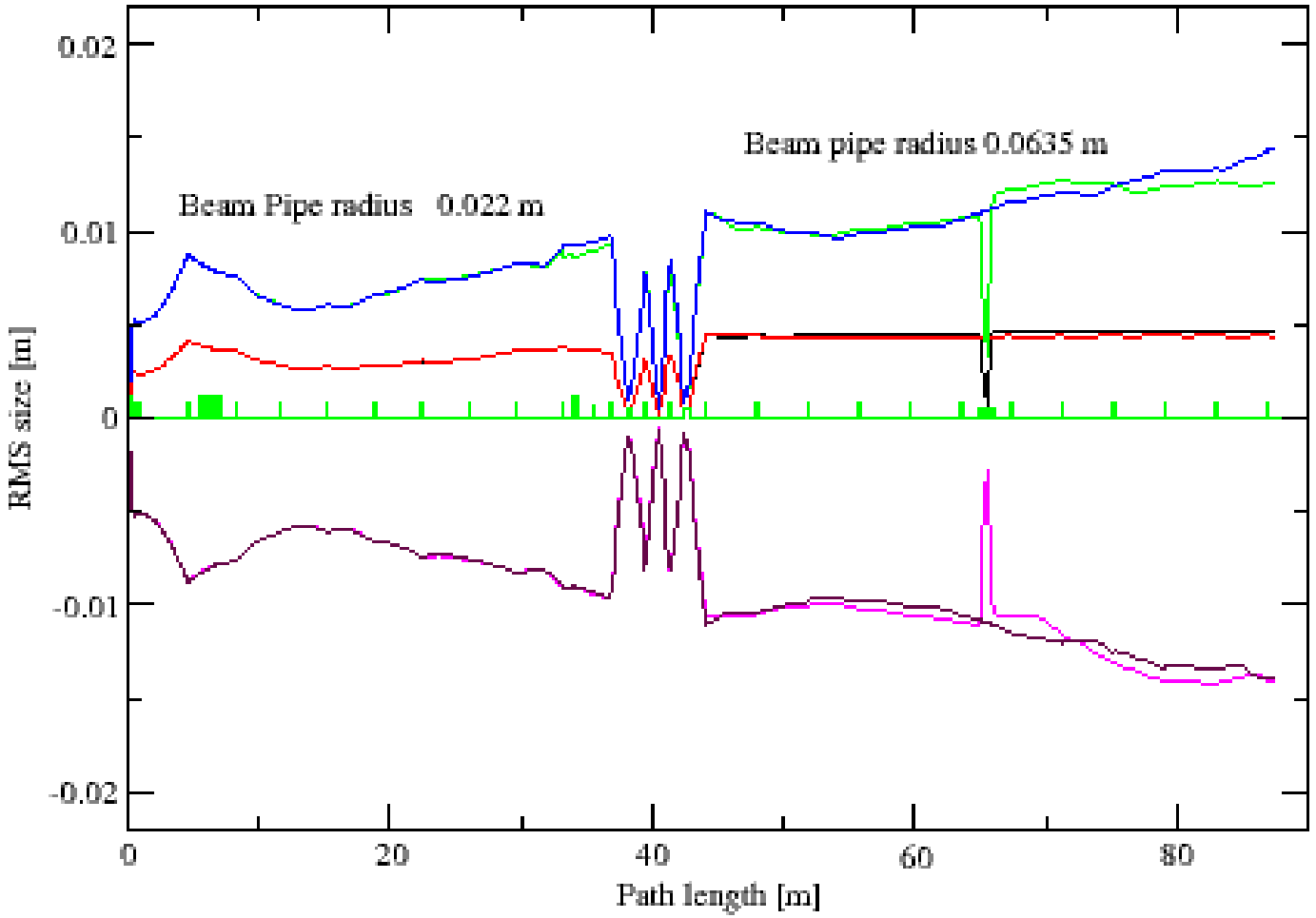
RMS Envelopes

LEReC with SRF gun



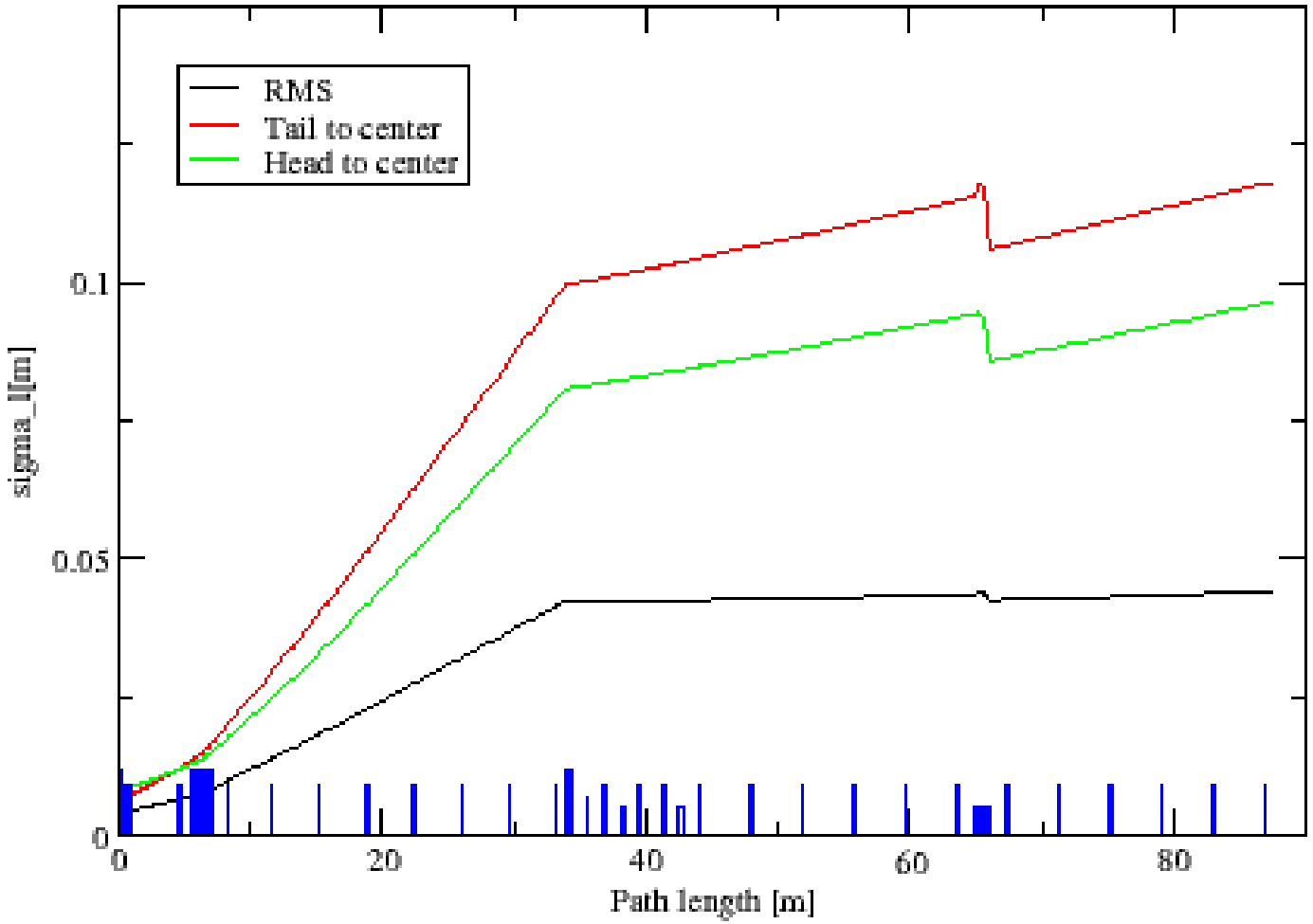
Max Envelopes

LEReC with SRF gun



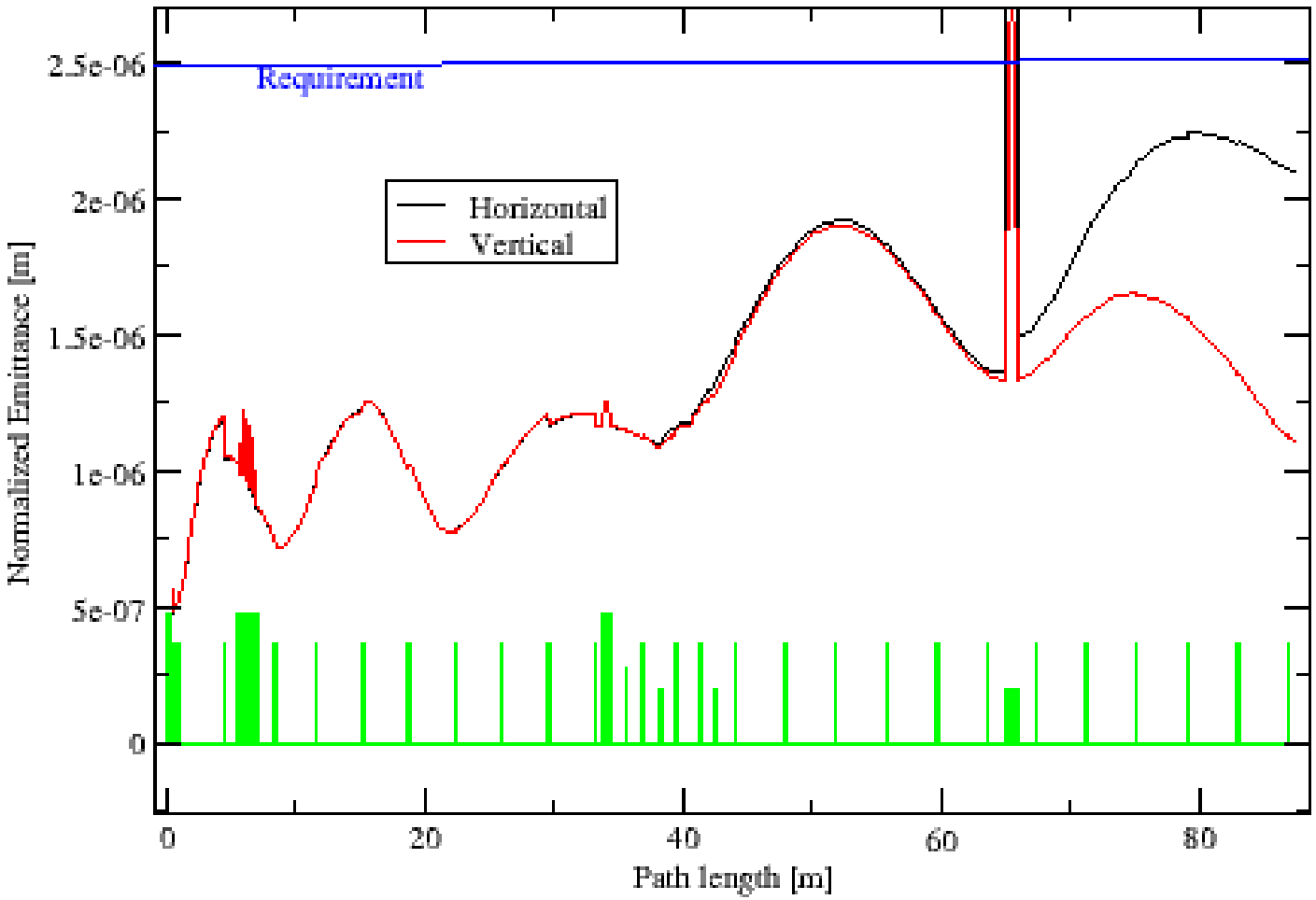
Bunch length

LEReC with SRF gun



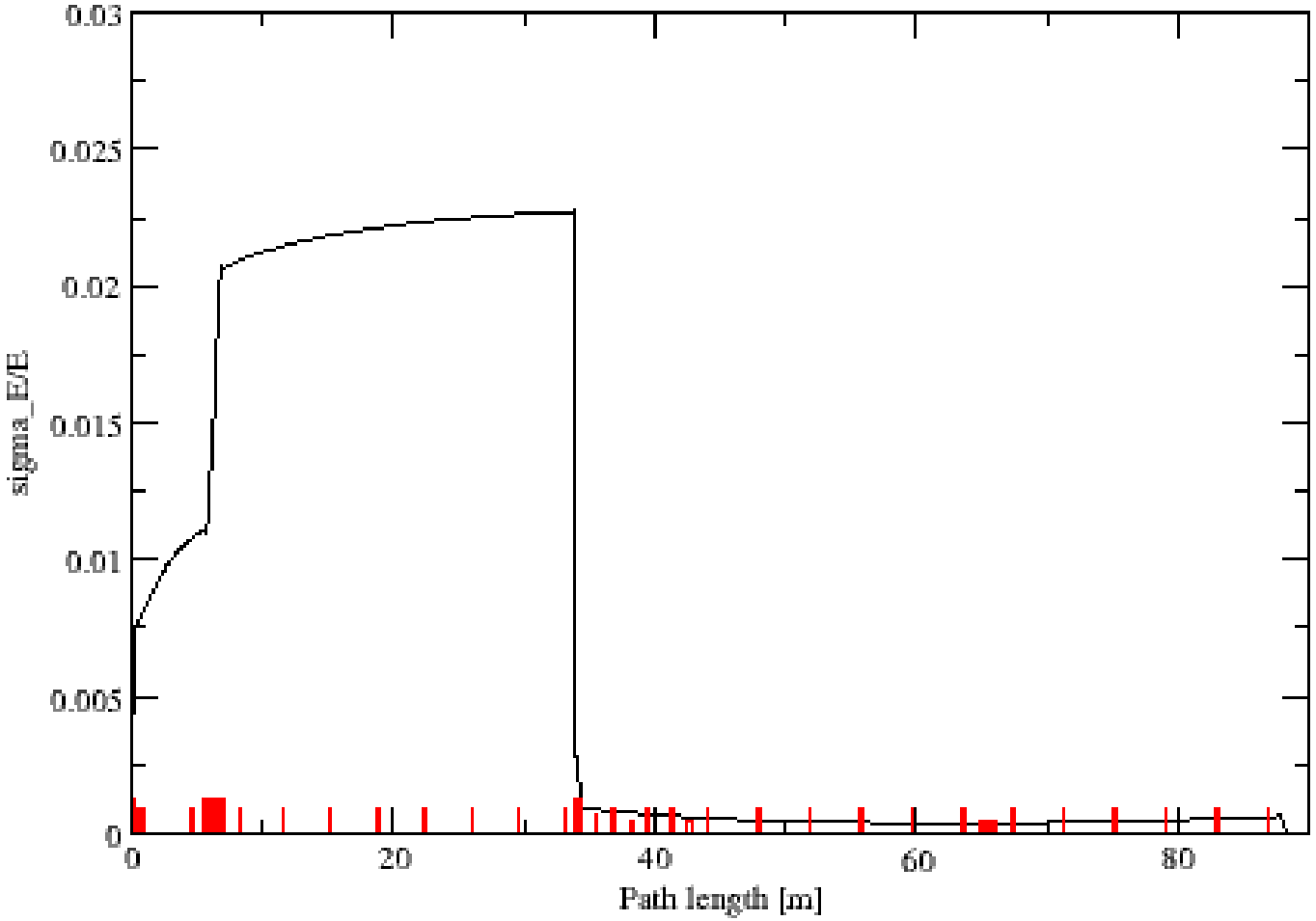
Normalized Emittances

LEReC with SRF gun



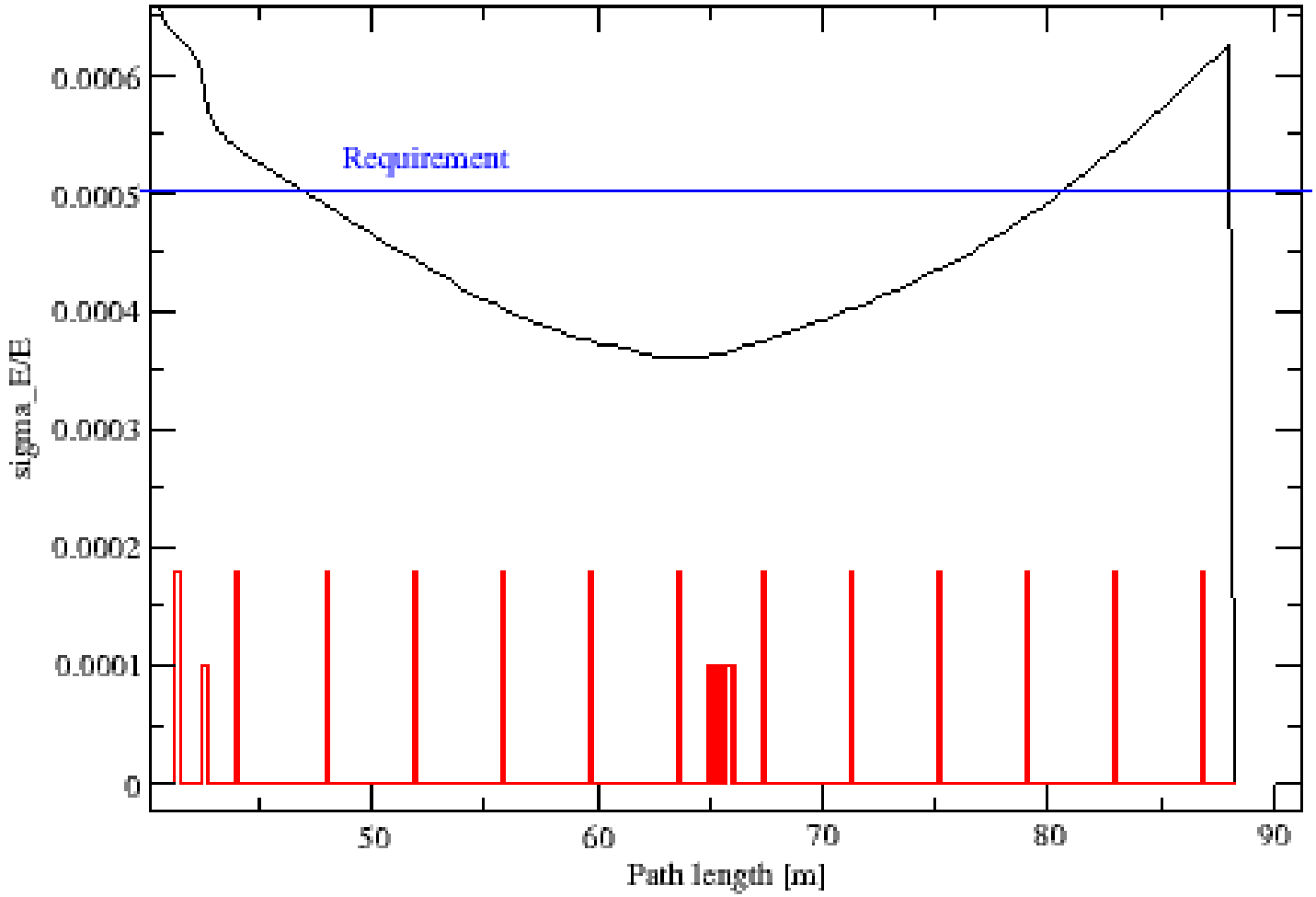
RMS Energy spread

LEReC with SRF gun



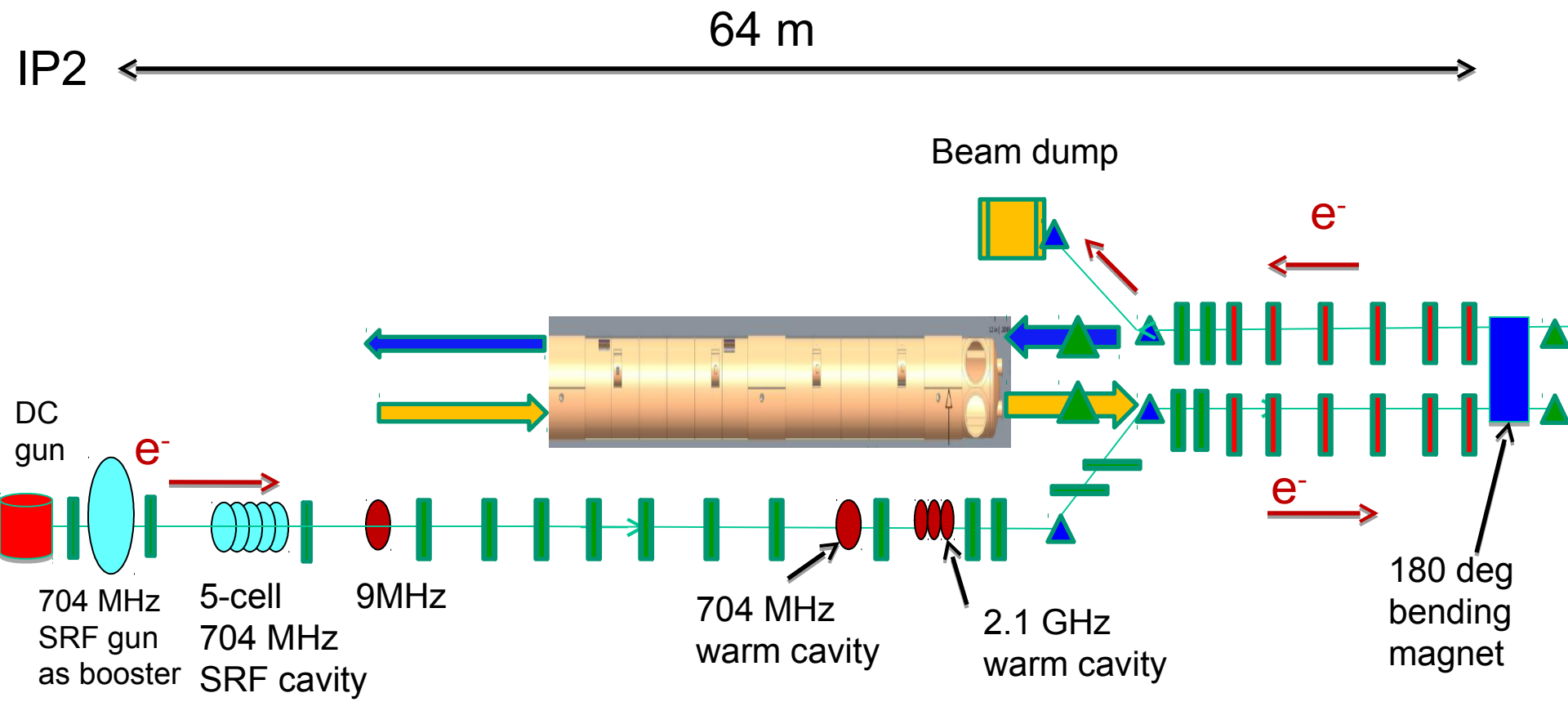
RMS Energy spread

LEReC with SRF gun



LEReC-I (1.6-2MeV): Gun to dump
SRF gun used as a booster cavity

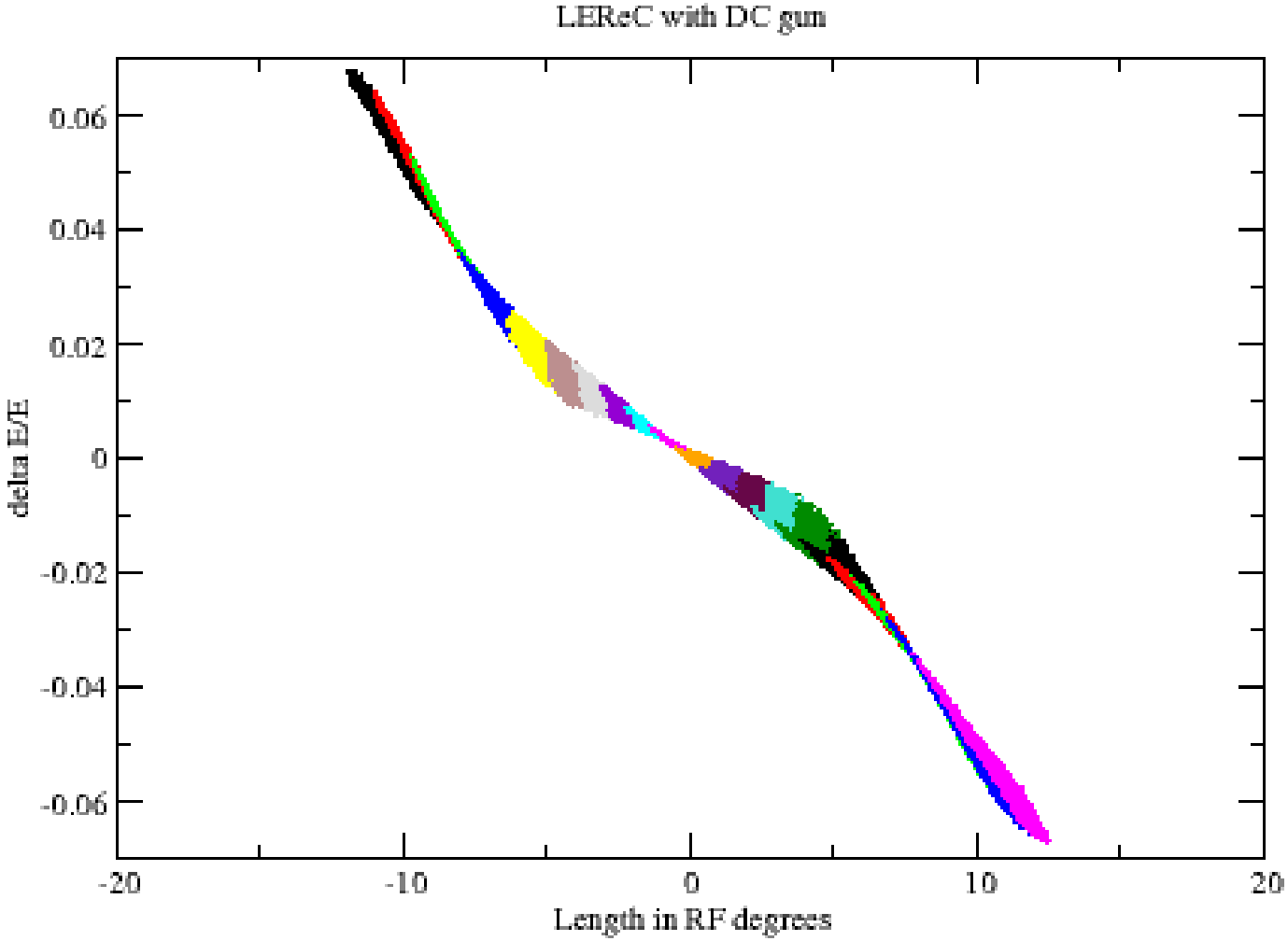
12/02/14



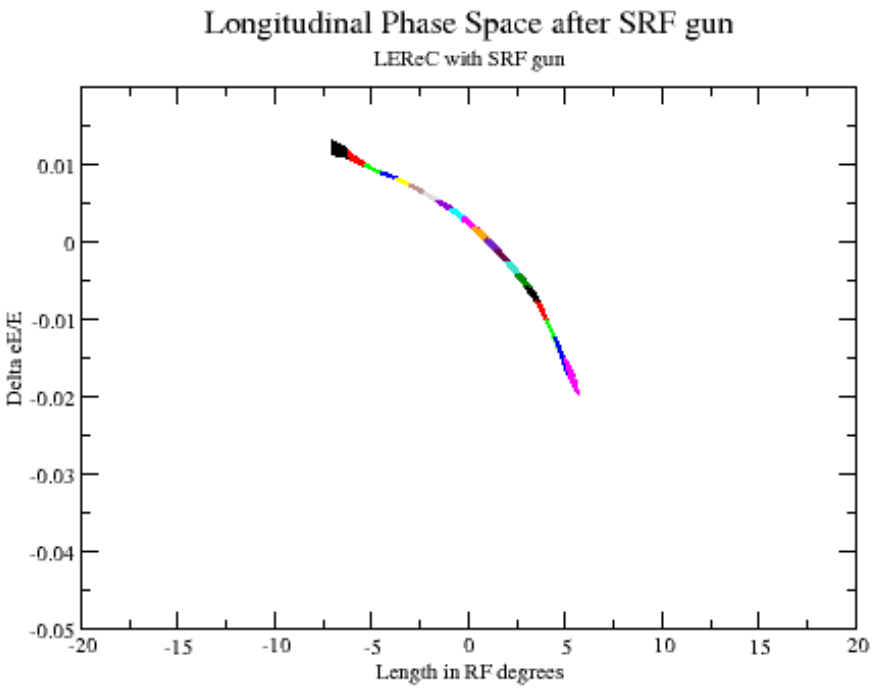
Beam optics with DC gun at 1.6 MeV

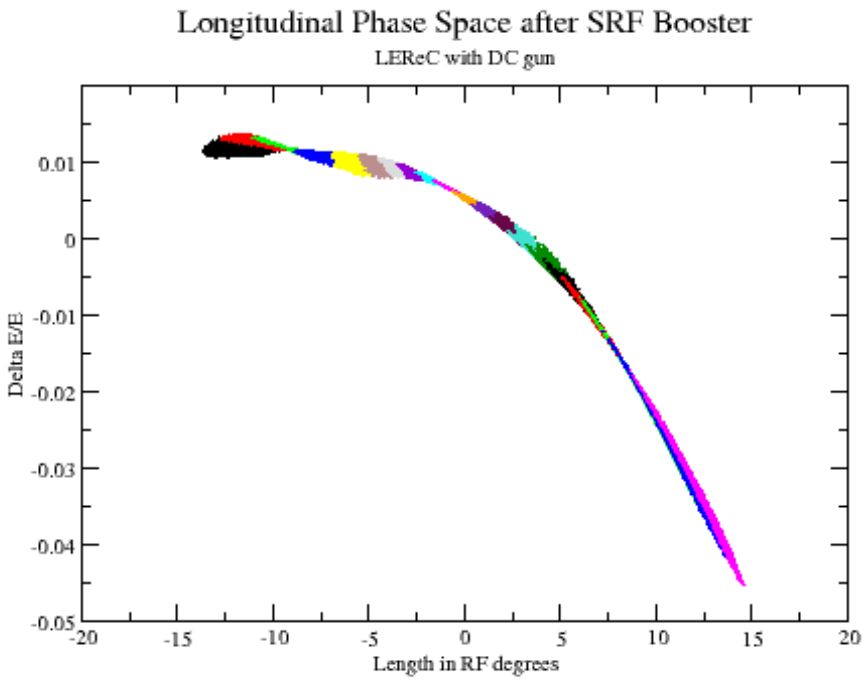
- The SRF gun becomes the SRF booster
- The SRF booster must be installed backwards
- The DC gun is installed as close as possible to the SRF booster, because the bunch length increases rapidly as the beam drifts
- The requirements are fulfilled for the emittance.
- The energy spread does not fulfill the requirements yet. We are working on it.
- In the following simulations we must add space for the laser port and correction coils. This will make the energy spread in the cooling section worse

Longitudinal Phase Space before the SRF Booster



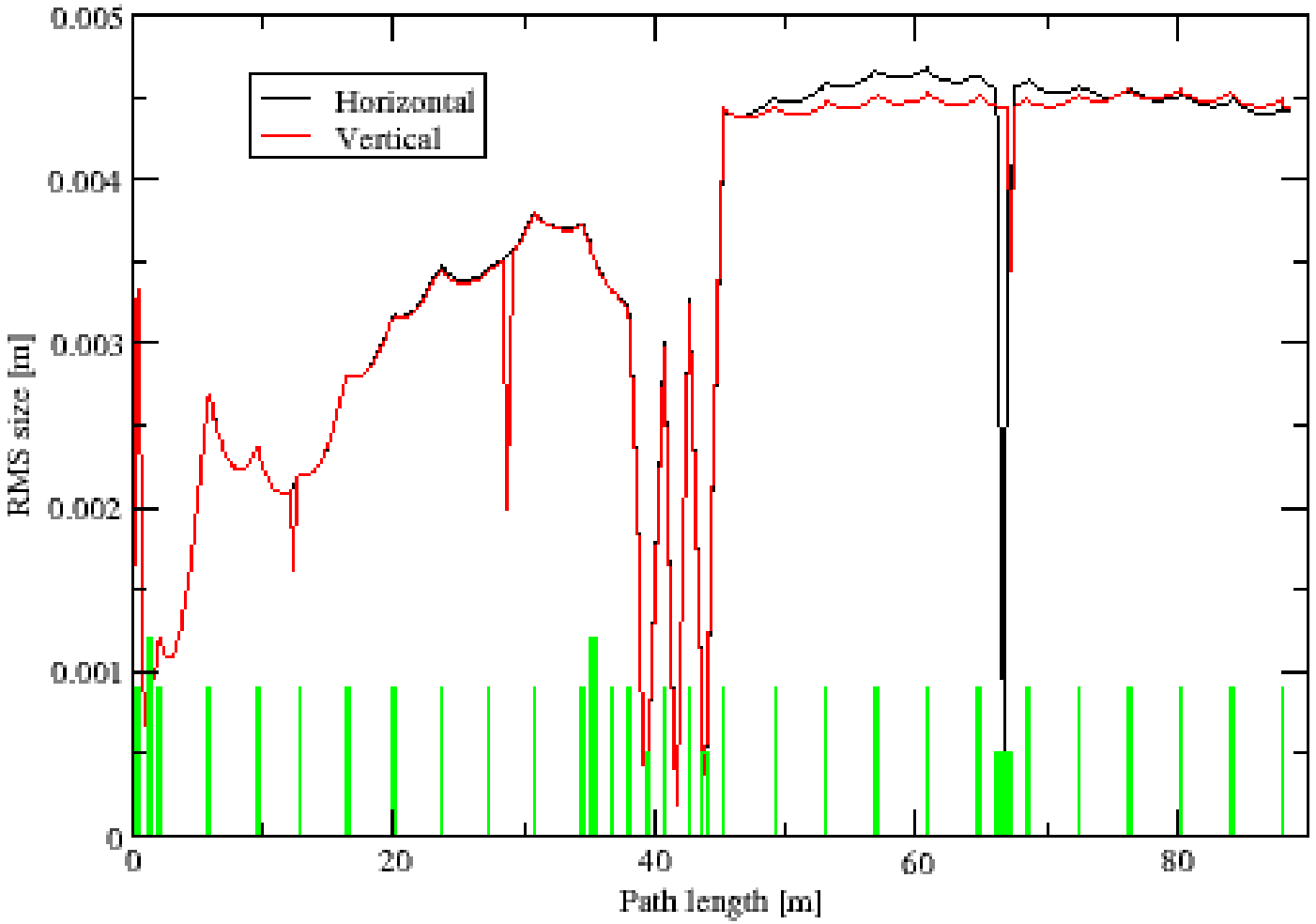
Longitudinal Phase Space after acceleration





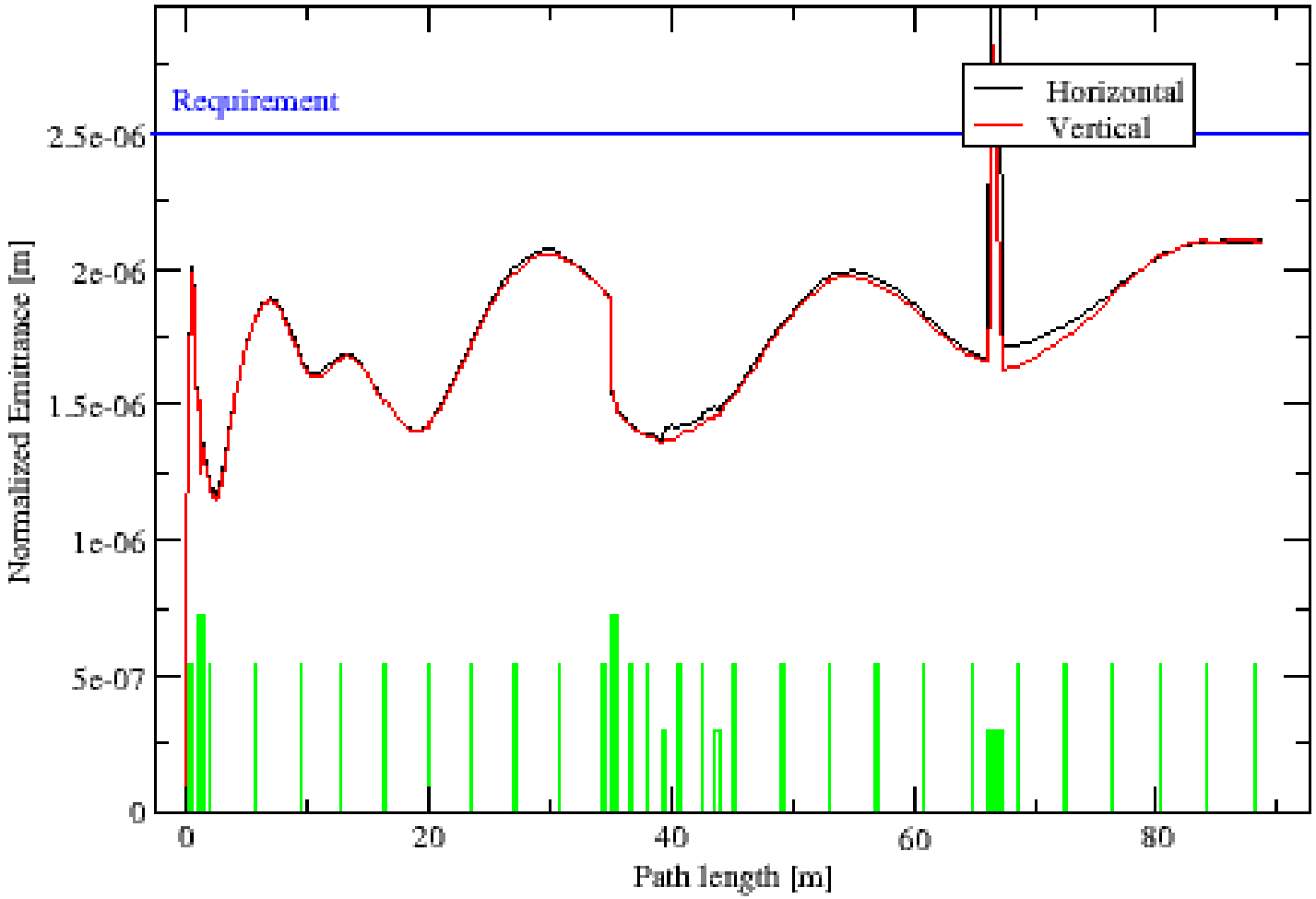
RMS Envelopes

LEReC with DC gun



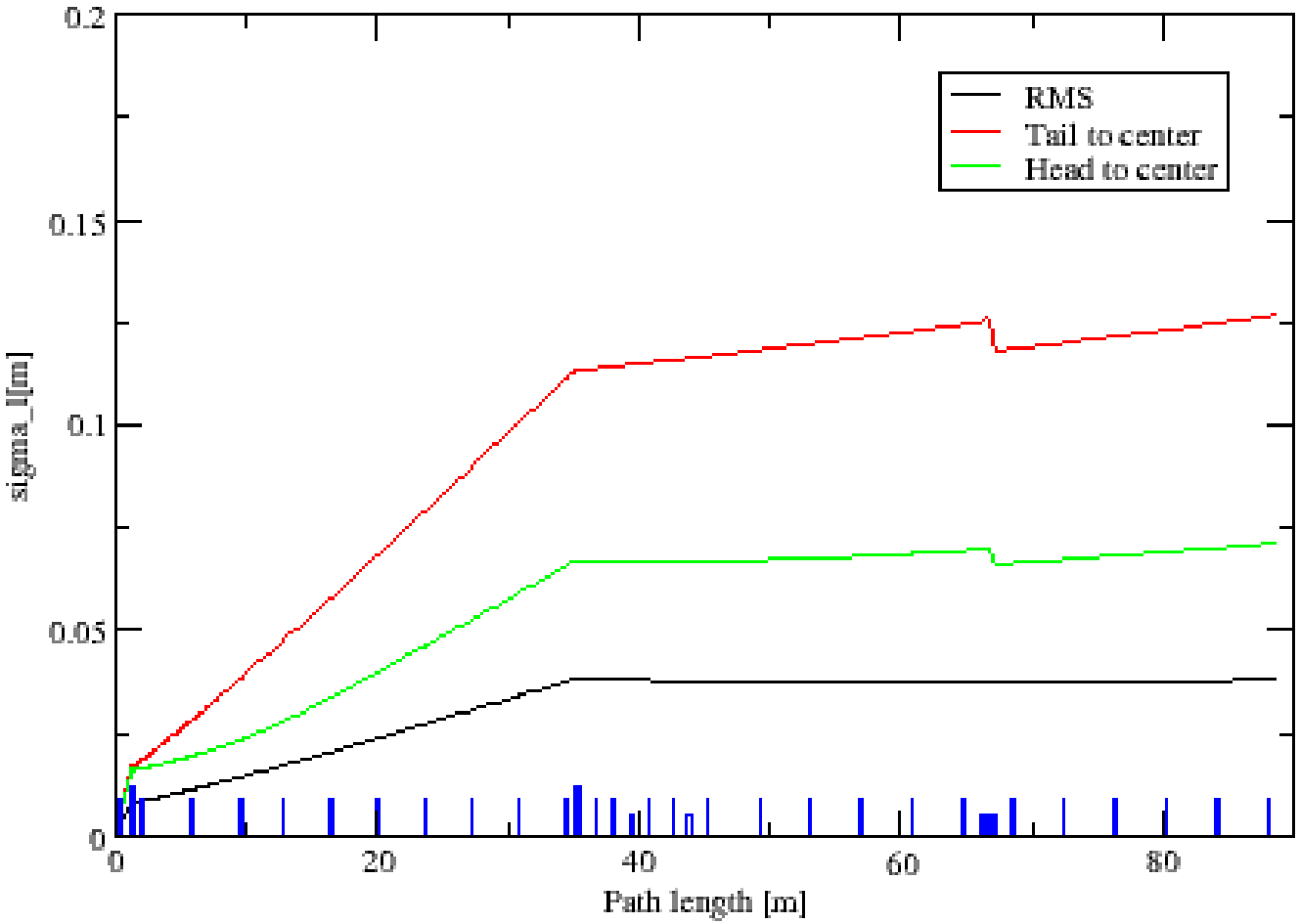
Emittances

LEReC with DC gun



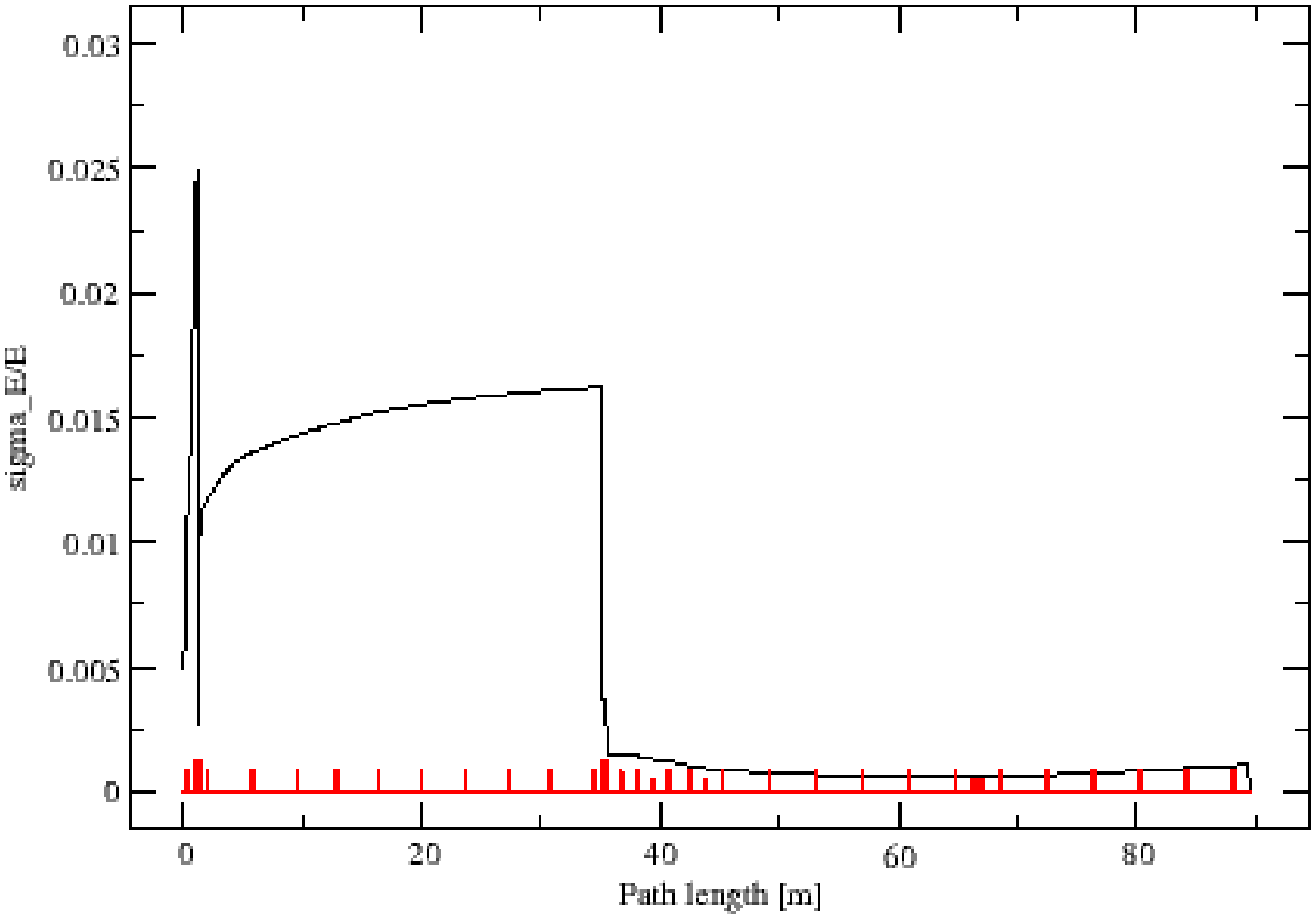
Bunch length

LEReC with DC gun



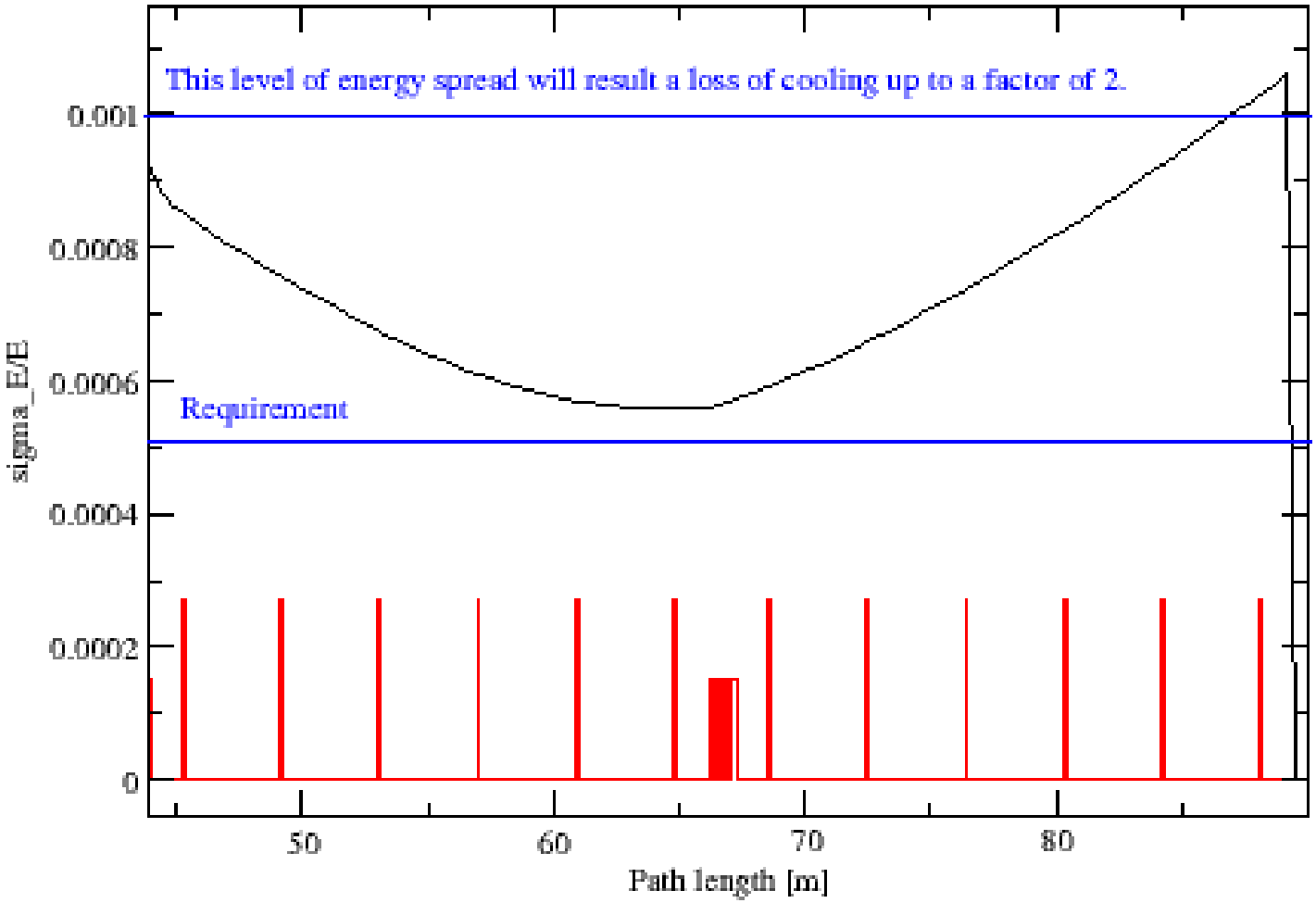
RMS Energy spread

LEReC with DC gun

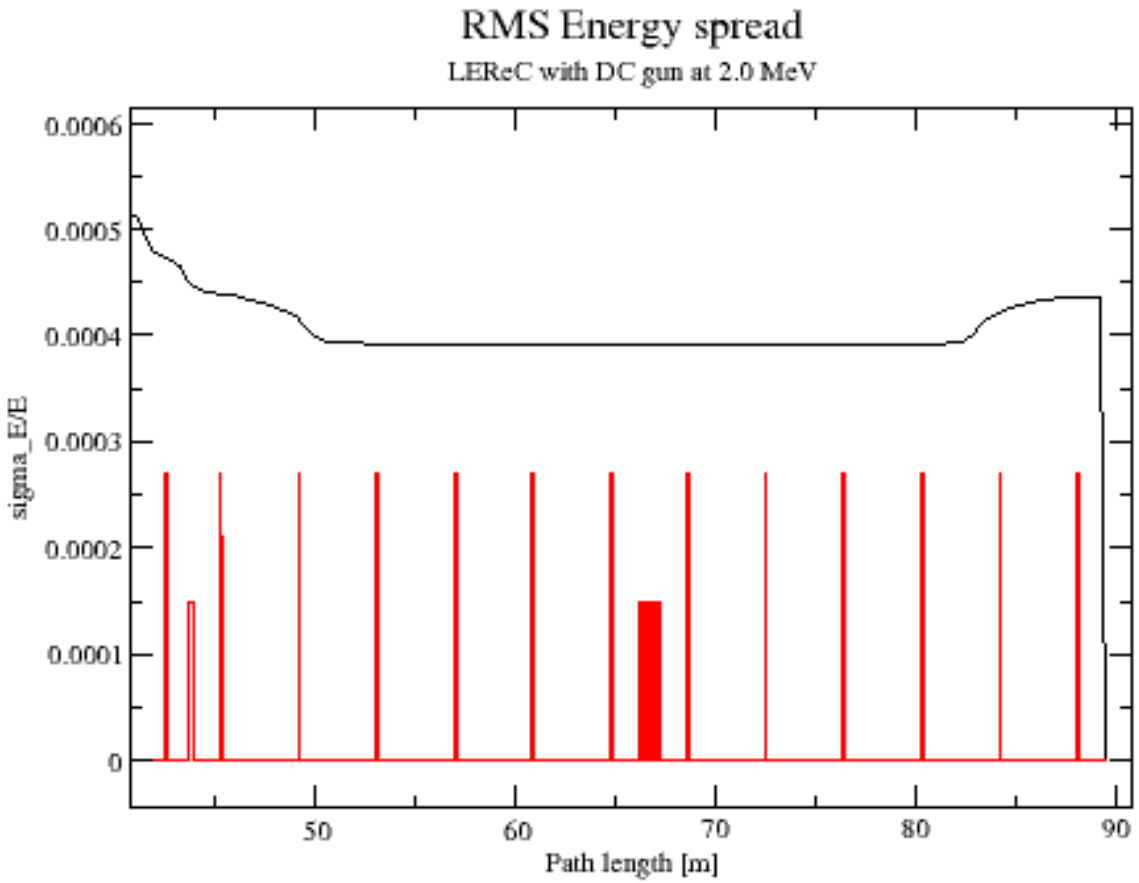


RMS Energy spread

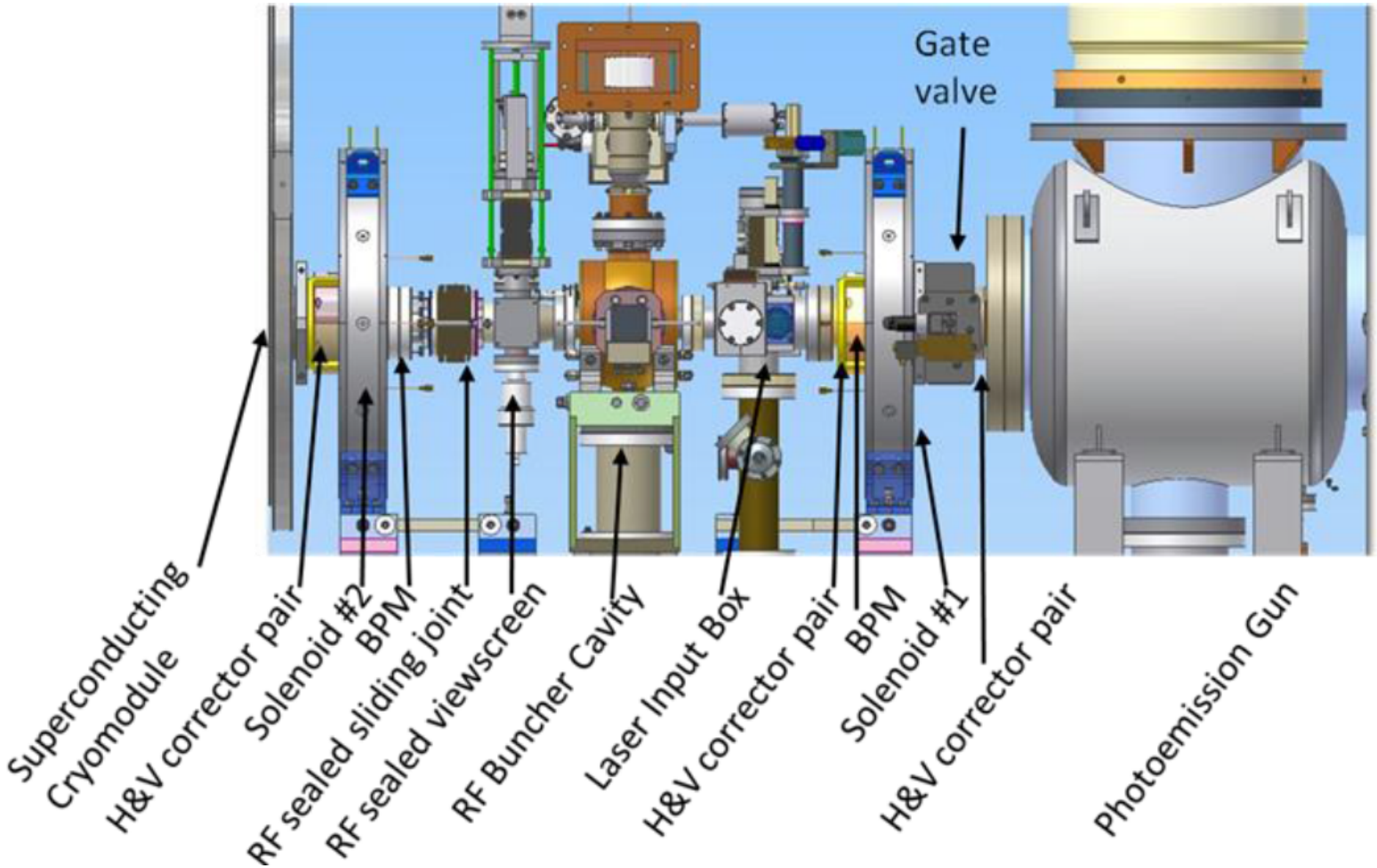
LEReC with DC gun



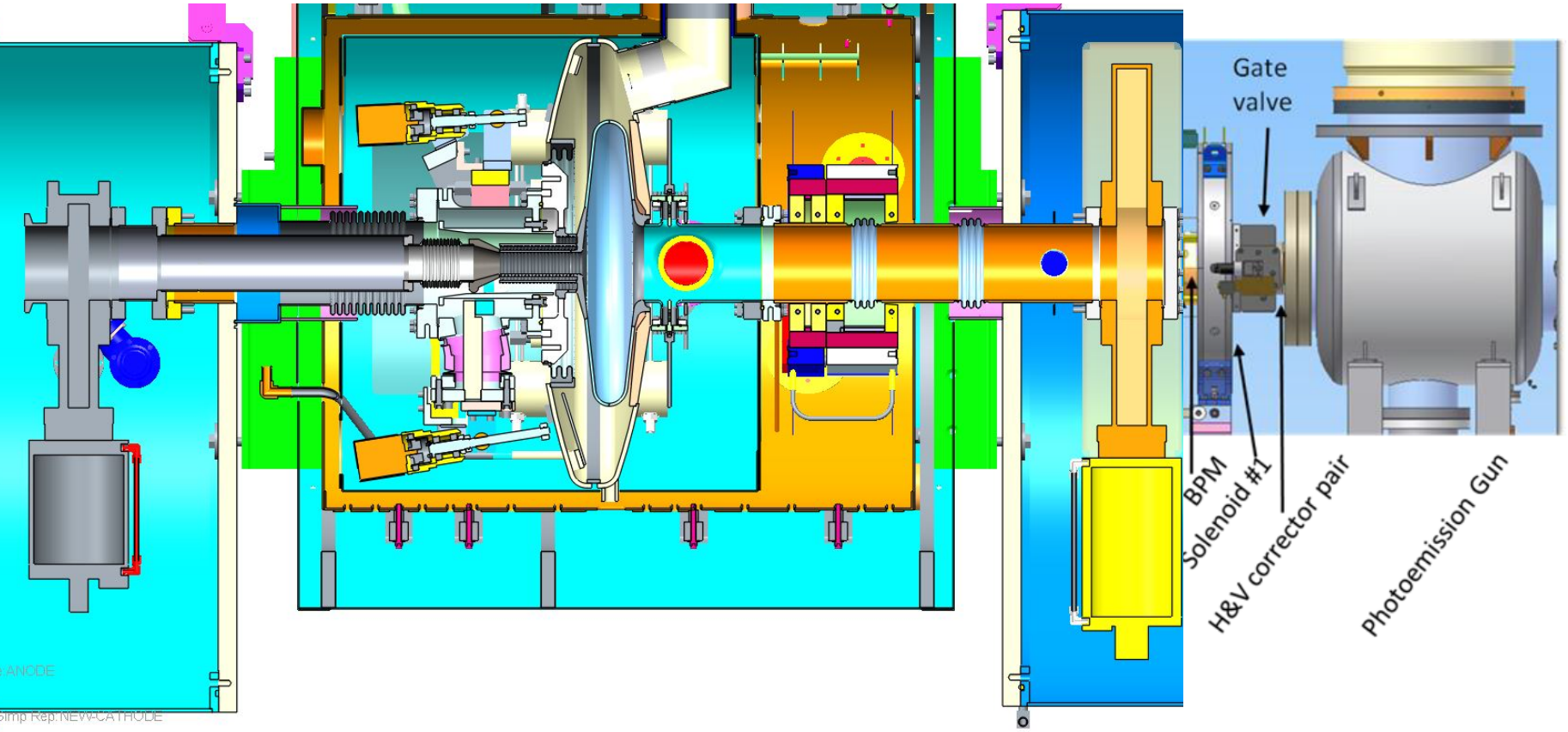
LEReC with DC gun at 2.0 MeV



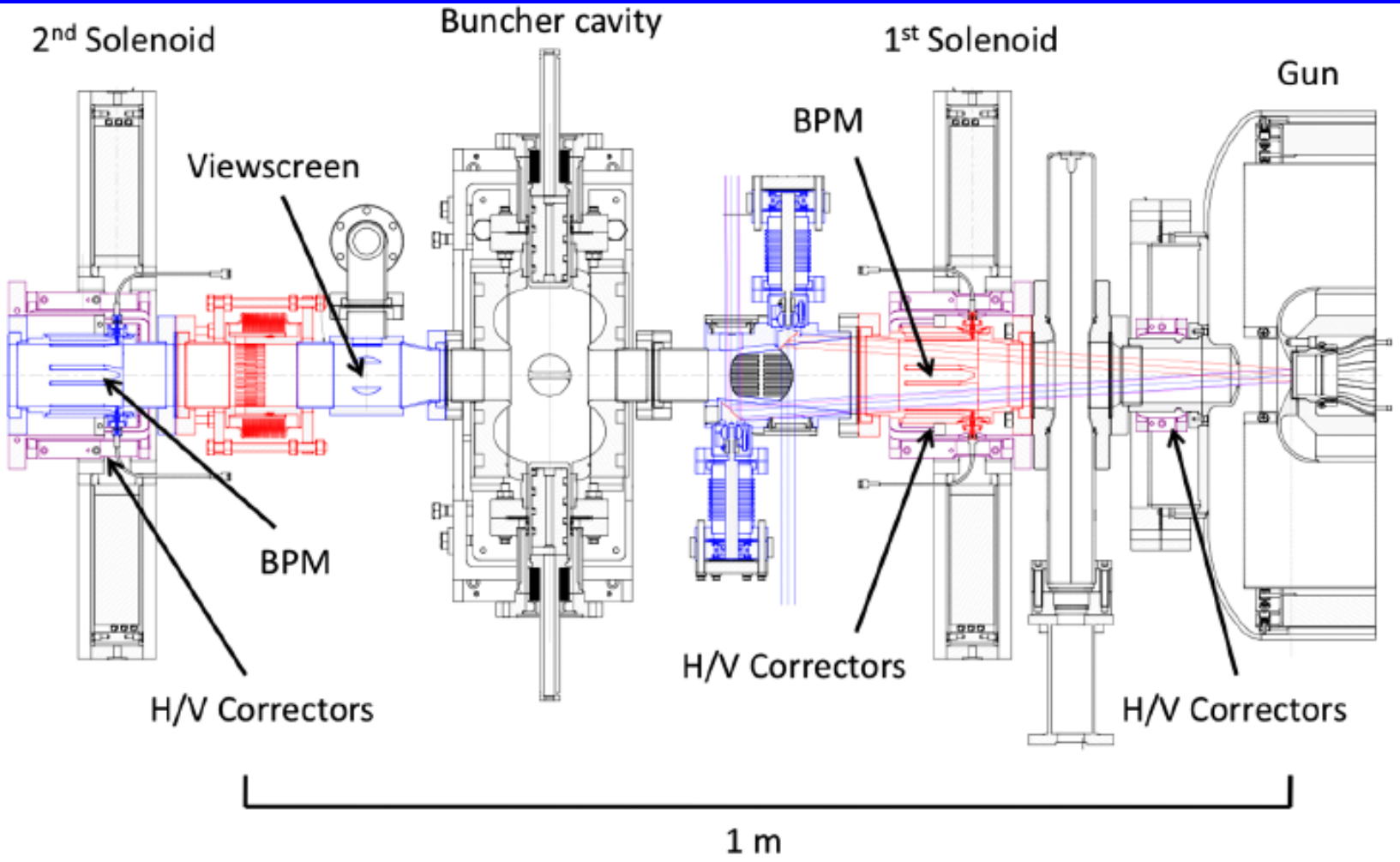
Layout of Cornell's injection line



Layout for the above simulation



Cornell's layout



Summary

- Our design fulfills the requirements for the operation using the SRF gun
- The design using the DC gun fulfills the emittance requirement, but not the energy spread goal yet, since we would like to move gun slightly further from the cryostat as well as to achieve good parameters with up to 300pC. Work is ongoing
- Everything is much easier at higher energies